

# Econophysics of interest rates and the role of monetary policy

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This paper presents empirical evidence using recently developed techniques in econophysics suggesting that the degree of long-range dependence in interest rates depends on the conduct of monetary policy. We study the term structure of interest rates for the US and find evidence that global Hurst exponents change dramatically according to Chairman Tenure in the Federal Reserve Board and also with changes in the conduct of monetary policy. In the period from 1960's until the monetarist experiment in the beginning of the 1980's interest rates had a significant long-range dependence behavior. However, in the recent period, in the second part of the Volcker tenure and in the Greenspan tenure, interest rates do not present long-range dependence behavior. These empirical findings cast some light on the origins of long-range dependence behavior in financial assets.

## I. INTRODUCTION

In the past decades the US economy has experienced low inflation and little variation in real activity if compared to the 1970's. These improvements have been largely attributed to a change in the way the Federal Reserve conducts monetary policy. A number of research papers have suggested that a structural break in the conduct of monetary policy has occurred since Paul Volcker became chairman of the Federal Reserve in August 1979 (see Clarida et al., 2000).

However, there is little consensus as whether a change in the conduct of monetary policy has indeed occurred and if it has what would be the dates of these changes (Boivin, 2005).

This paper adds to the debate on monetary policy by studying changes in persistence in interest rates for different maturities for the US. We investigate 1, 3, 5 and 10 year maturity interest rates and present overwhelming evidence that a structural break has occurred in the dynamics of these interest rates. We employ methods recently developed in statistical physics and show that interest rates' persistence has decreased substantially in the post-1982 period, while there is evidence of strong long-range dependence in the pre-1982 period. Therefore, the evidence in this paper is in line with the reasoning that a structural break has occurred in the conduct of monetary policy in the early 1980's.

This paper proceeds as follows. In section 2, a brief review of the literature is presented. In section 3, the methodology to estimate generalized Hurst exponents is reviewed. In section 4, the data used in this work is described. Section 5 presents the empirical results. Finally, in section 6, this paper is concluded.

## II. BRIEF LITERATURE REVIEW

Researchers have documented a substantial change in macroeconomic variables for the US in the past decades.

From the late 1960s through the early 1980s, the United States economy experienced high and volatile inflation along with several severe recessions. Since the early 1980s, however, inflation has remained steadily low, while output growth has been relatively stable.

When Arthur Burns became chairman in February 1970, the inflation rate had reached nearly 6 percent, yet almost immediately, monetary policy became more accommodating in that the Federal Open Market Committee (FOMC) lowered the targeted federal funds rate and money growth exploded. Over the period 1965 through the end of the 1970s, monetary policy earned the appellation stop-go from the FOMC's alternate concentration on reducing inflation and stimulating economic activity.

The initial period of Volcker's tenure as chairman, August 1979 through 1982, can be thought of as the final stop phase of the preceding stop-go period. In that period the Federal Reserve announced a change in operating procedures from partially targeting interest rates to targeting nonborrowed reserves. This period, from October 1979 to August 1982, is known as the monetarist experiment.

In 1982 the Volcker Federal Reserve began targeting the fed-funds rate. From the mid-1980s onward, monetary policy consistently responded strongly to inflation and weakly to real-activity. This interest-rate targeting continued in the Greenspan administration.

Romer and Romer (2003) study why monetary policy has been so much successful under some Federal Reserve chairmen than others. The authors argue that the key determinants of policy success have been policymakers views about the economy and limitations of monetary policy.

Several papers have documented that a change in monetary policy has occurred in the early 1980's. Clarida et al. (2000) provide empirical evidence of important changes in the U.S. conduct of monetary policy over the last forty years. In particular they find that while monetary policy accommodated inflation in the 1970s, this drastically and suddenly changed with the appointment of Volcker in 1979. They emphasize that the pre-Volcker

conduct of monetary policy did not satisfy the so-called Taylor principle, so that a given increase in inflation was typically associated with a smaller increase in the nominal interest rate. The authors show that in the Volcker-Greenspan era the Federal Reserve adopted a proactive stance toward controlling inflation. Duffy and Engle-Warnick (2004) study changes in monetary policy over the 1995-2003 period and find evidence of three structural breaks, one of them in the beginning of the Volcker's Federal Reserve chairmanship[25].

The literature cited above has discussed whether and when structural breaks have occurred in the conduct of monetary policy. The overall conclusion is that changes have occurred in the dynamics of inflation and real activity. Therefore, we will study the dynamics of interest rates (long memory) and test whether changes have occurred in the dynamics of these variables evaluating different time periods, according to hypothesized changes in monetary policy and Federal Reserve chairman.

The first to consider the existence of long memory in interest rates seems to be Backus and Zin (1993) who find evidence of long-memory in the 3-month zero-coupon rate for the US, and that allowing for long memory in the short interest rate improves the fitted mean and volatility yield curves. The authors have suggested that the sources of the long-memory property of the short-term interest rate may be derived from a fractionally integrated dynamic for inflation and/or the money growth rate.

Since then, others have supported Backus and Zin (1993) results. For example, Tsay (2000) has showed that the ex post real interest rate for the US possesses long memory. The author employed unit root tests due to Kwiatkowski *et al.* (1992) and Phillips and Perron (1988). For most of the samples the authors analyze the rejection of both hypothesis suggest that these processes are neither an  $I(1)$  or  $I(0)$  process. Therefore, an ARFIMA model was estimated and empirical evidence suggested that ex post real interest rates could be well described by an ARFIMA model with long memory. Other evidences are provided by Barkoulas and Baum (1998) employing spectral regression and Gaussian semiparametric methods to the Euroyen deposit rates and Euroyen term premium and McCarthy *et al.* (2004) applying wavelets to a large class of US debt instruments. In particular, the authors in Cajueiro and Tabak (2005a) have found an interest evidence of this phenomenon studying the long-range dependence behavior of the term structure of interest rates in Japan where the predictability in the term structure of interest rates increases with maturity. In their paper this phenomenon is explained by the nonnegative constraint in the interest rate.

The contribution of this paper is that we study long memory properties for interest rates for different time periods and check whether a structural break has occurred, which is suggestive of changes in monetary policy.

### III. MEASURES OF LONG-RANGE DEPENDENCE

Several methods have been introduced to take the long-range dependence phenomenon into account[26]. This literature can be actually divided in two different strands: (1) an approach whose focus is to determine the parameter known as the Hurst exponent or a parameter related to it (see, for example Geweke and Porter-Hudak (1983), Hosking (1981), Hurst (1951), Robinson (1995) and Cajueiro and Tabak (2005b)) and (2) an approach that aims at developing statistics to test, through a hypothesis test, the presence of long-range dependence (see, for example, Giraitis *et al.* (2003), Lee and Schmidt (1996) and Lo (1991)).

In this paper, our measure of long range dependence is the Generalized Hurst exponent introduced in Barabasi and Vicsek (1991) and considered recently by Di Matteo *et al.* (2005) to study the degree of development of financial markets. The generalized Hurst exponent is a generalization of the approach proposed by Hurst. The authors suggest analyzing the  $q$ -order moments of the distribution of increments, which seems to be a good characterization of the statistical evolution of a stochastic variable  $X(t)$ ,

$$K_q(\tau) = \frac{\langle |X(t+\tau) - X(t)|^q \rangle}{\langle |X(t)|^q \rangle}, \quad (1)$$

where the time-interval  $\tau$  can vary[27]. The generalized Hurst exponent can be defined from the scaling behavior of  $K_q(\tau)$ , which can be assumed to follow the relation

$$K_q(\tau) \sim \left(\frac{\tau}{\nu}\right)^{qH(q)}. \quad (2)$$

### IV. DATA

The data is sampled daily, beginning on January 2, 1962 and ending on February 4, 2005. The full sample has 10755 observations, collected from the Federal Reserve System. We study the 1,3,5 and 10-years to maturity interest rates, which are constant maturity treasury rates.

We test for long-range dependence in log interest rates for different time periods. We split the sample according to monetary policy and also to Federal Reserve tenure. Table 1 presents the tenure period for each chairman. We do not study the Miller administration because it was too short.

### V. EMPIRICAL RESULTS

Recent research has documented that a change may have occurred in the way monetary policy has been conducted in the US in the past decades (see Clarida *et al.*,

Federal Reserve Chairman	Period
W. Martin	Apr. 1951 - Jan. 1970
A. Burns	Feb. 1970 - Jan. 1978
G. Miller	Mar. 1978 - Aug. 1979
P. Volcker	Aug. 1979 - Aug. 1987
A. Greenspan	Aug. 1987 - Feb. 2006

This table presents the tenure of each Chairman of the Federal Reserve since the 1950's.

	y1	y3	y5	y10
Panel A: Federal Reserve Chairman				
Martin	0.64	0.59	0.59	0.59
Burns	0.64	0.63	0.62	0.62
Volcker	0.58	0.58	0.58	0.56
Greenspan	0.50	0.50	0.50	0.49
Panel B: Monetary Policy				
Pre 1979	0.63	0.61	0.61	0.61
Post 1979	0.53	0.52	0.52	0.51
Monetarist Experiment	0.60	0.59	0.59	0.57
Post 1982	0.50	0.50	0.51	0.50

This table presents generalized Hurst exponents for 1,3,5 and 10-year interest rates for different time periods.

2000, and Boivin, 2004). Therefore, we study the behavior of interest rates for different maturities and compare generalized Hurst exponents for a variety of time periods.

Table 2 presents generalized Hurst exponents for different time periods. Panel A presents estimates according to Federal Reserve chairman. Hurst exponents are decreasing with maturity, which suggests that short-term interest rates are more predictable than long-term interest rates. It is striking that these Hurst exponents are close to 0.5 for the Greenspan era for all maturities, and are very high for the Burns era (above 0.62 for all maturities).

We would also like to test whether there is an influence of the monetarist experiment conducted in the beginning of the Volcker administration. Panel B shows results dividing the sample in a different way. We see that interest rates were quite persistent in the monetarist experiment in the beginning of the Volcker administration. However, they converge to values similar to the ones seen in the Greenspan administration afterwards.

The empirical results obtained suggest that the dynamics of interest rates has changed substantially in the

past decades. Long-range dependence seems to be strong in the pre-1982 period, while this evidence practically disappears in the recent period (post-1982), coinciding with substantial changes in the conduct of monetary policy.

## VI. CONCLUSIONS

Testing for long-range dependence in asset prices has been subject of intense investigation in the financial literature. There are many implications for portfolio and risk management. For example, traditional option pricing models should be modified to incorporate long-range dependence features in asset prices and volatility. Furthermore, if the long-range dependence parameters change over time, then the time series that are being studied possess more information than is given by monofractal models. Therefore, studies that focus on how and why long-range parameters change over time may be particularly useful as they can be used to determine structural breaks or shifts in these time series.

This paper offers a fresh look at the properties of interest rates for the US. The empirical evidence suggests that interest rates had strong long memory in the pre-Volcker administration and that after 1982 this evidence has disappeared. These results suggest a structural break in the dynamics of interest rates. They also imply that careful should be taken when studying long time series as the parameters that characterize them may change over time, which is evidence of multifractality.

It is important to notice that our sample period includes important changes in the macroeconomic environment, as exchange rates become flexible in the mid 1970's and early 1980's. Therefore, in a fixed exchange rate framework shocks to the economy must be absorbed mainly by movements in interest rates, which implies in more persistent interest rates' dynamic. However, in flexible exchange rate regimes policy makers have more degrees of freedom to absorb shocks into the economy, as exchange rates may absorb partially such shocks.

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